

Global 21-cm Data Analysis Pipeline to Constrain Physical Parameters using Lunar-based Observations.

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Low-radio-frequency instruments either orbiting the Moon or on the lunar surface would be able to avoid ionospheric, solar emission and Earth's radio-frequency-interference effects. To measure with precision the sky-averaged 21-cm signal of neutral hydrogen from the Dark Ages and Cosmic Dawn using observations from such lunar-based telescopes, we are developing a complete data analysis pipeline which consists of three distinct steps.

First, using a pattern recognition code, *pylinex* (publicly available¹), we extract the signal from large beam-weighted foregrounds and instrument systematics, independently of any physical model. To crucially increase the separation power between signal and foregrounds, we incorporate a novel technique that takes advantage of the polarization induced by the rotation of anisotropic foregrounds seen by a large-beam antenna, in contrast with the isotropic, unpolarized 21-cm signal. In Figure 1, we show examples of the success of this first step of the pipeline by generating realistically simulated data from which we recover and constrain inputted signals. This powerful implementation of the polarization technique is to be demonstrated in space by a SmallSat mission-concept in lunar orbit we have developed to propose to NASA: the Dark Ages Polarimeter Pathfinder (DAPPER).

Second, we employ a multidimensional interpolation technique (using a Delaunay mesh; see Figure 2) to translate an extracted signal into a chosen physical parameter space, from which we initiate the final step of the pipeline, a Markov-Chain-Monte-Carlo (MCMC) exploration of the probability distribution in that space.

This sequence allows us to circumvent the fact that current theoretical models of 21-cm brightness temperature imprints from the first stars and black holes as well as exotic physics, such as interactions of baryons with dark matter particles as recently re-proposed, vary widely. The present lack of knowledge on the underlying physical parameters makes finding the starting point for an MCMC analysis of critical importance for an efficient search.

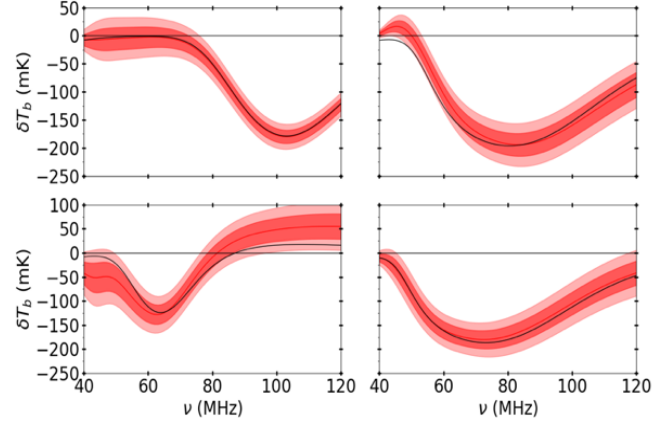


Figure 1: Four representative signal extractions (out of 5000) using the code *pylinex*, which uses a linear model defined by Singular-Value-Decomposition (SVD) modes calculated from signal and systematics training sets. The black curves show input signals, the red curves recovered signals, and the dark/light red bands their posterior 68/95% confidence regions (see further details in Tauscher et al. 2018, ApJ, 853, 187).

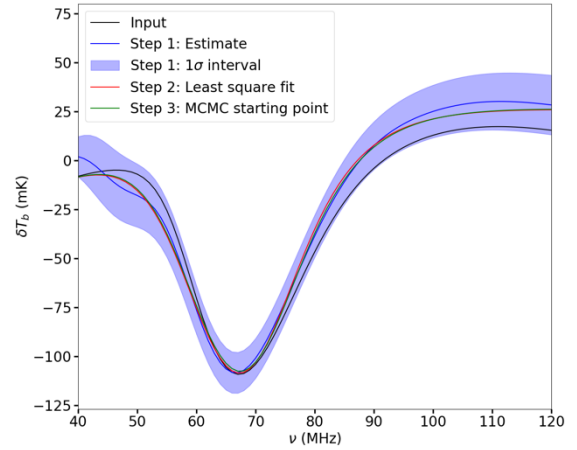


Figure 2: Performance of our arbitrary-dimensions interpolation procedure to convert an SVD signal estimate from *pylinex* (blue curve and band) into a best-fit physical model (green curve) from which to efficiently start an MCMC exploration of this parameter space (Rapetti et al., in preparation).

¹<https://bitbucket.org/ktausch/pylinex>